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Engineering Report

PERSHING TRANSPORTABILITY STUDY

Foreign Railways, Vol. III of IV

July 1966

UNITED STATES ARMY TRANSPORTATION ENGINEERING AGENCY
T.E.A.
SEMPER SERVIDIUM

U. S. ARMY

TRANSPORTATION ENGINEERING AGENCY

FORT EUSTIS, VIRGINIA

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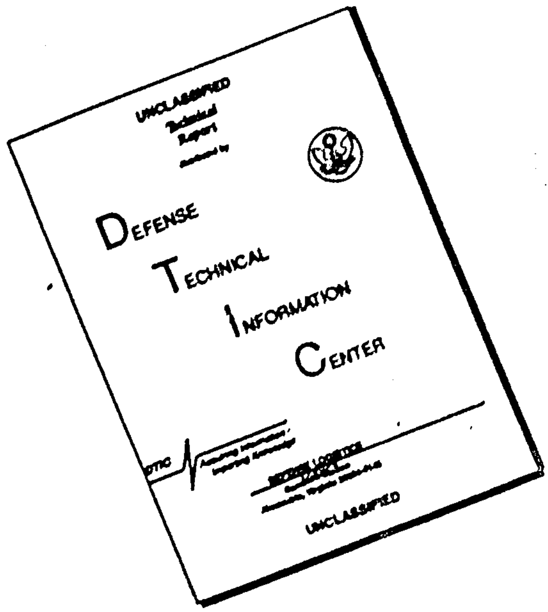

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ENGINEERING REPORT

PERSHING TRANSPORTABILITY STUDY,

Foreign Railways

Volume III of IV

July 1966

Prepared by

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CONTENTS

ABSTRACT

Foreign railcars were used in conducting rail impact tests on Pershing missile system first and second stage motor containers, XM 475 and XM 476. Data from the tests will be used in evaluating the effects of the foreign rail environment on the containers and in determining if the procedures used in restraining the containers for CONUS rail shipment would be applicable to foreign rail shipment.

The CONUS rail shipment restraining arrangement evaluated during this study was basically in conformance with pages 4 and 9 of Savanna Army Depot Drawing No. 5425.

Dynamic loadings induced by impacting the test car were measured electronically. The input forces were determined at impact by specially designed dynamometers mounted between the buffers and the car end sill. The car and container responses were measured by strain gage accelerometers.

Results of the study showed that the container skid bolts do not have the required structural strength to resist the dynamic loading imposed by rail impacts. The ½-inch-diameter bolts attaching the skid to the container experienced shear failure at impact velocities of 7 miles per hour when the container skid was not abutted flush with the forklift receptacle.

The results of the study also indicated that the restraining arrangement providing transfer of shocks into the forklift receptacle rather than to the container skids is the preferred arrangement.

I. INTRODUCTION

During a meeting at Savanna Army Depot, 24-25 June 1965, on "Transportability Criteria," engineers of various Army commands and agencies reviewed problems encountered in the movement worldwide of the Pershing missile system. As a result of this meeting and subsequent meetings, a program to conduct a scientific "Transportability Study on Movement Worldwide of the Pershing Missile System" was prepared (Reference 2). The purpose of this program is to establish transportability criteria that will serve as a basis for the development of movement standards and procedures.

A meeting was held in the Office of the Deputy Chief of Staff for Logistics, Transportation Engineering Office (DCSLOG/TENO), 21-22 September 1965, to review, coordinate, and approve the study. Participating agencies included representatives of DCSLOG/TENO; U.S. Army Materiel Command (USAMC); U.S. Army Supply and Maintenance Command (USASMC); Military Traffic Management and Terminal Service (MTMTS); Headquarters, Eastern Area, Military Traffic Management and Terminal Service (HQ, EAMTMTS); U.S. Army Missile Command (USAMICOM); and the U.S. Army Transportation Engineering Agency (USATEA). Approval was obtained and USATEA was instructed to conduct the transportability study.

This report, Volume III of the Pershing Transportability Study, presents the results of the foreign railway study. Other reports on the Pershing Transportability Study include: Volume I, Calculations and Analysis of Railway Tests; Volume II, CONUS Railways; and Volume IV, Vessel Stowage.

II. OBJECTIVES

1. To develop transportability criteria on which to base shipping standards and procedures for movement of the Pershing missile system by foreign rail transport.

2. To evaluate the structural integrity of XM 475 and XM 476 container restraining arrangements designed for CONUS railcar shipments and to determine whether the arrangements are suitable for foreign railcar shipments.

3. To determine whether correlation can be obtained between mechanical shock recorders and electronic techniques for measuring shock responses occurring during railcar impacts.

III. CONCLUSIONS

1. The current loading arrangement shown in Figure 6, combined with container construction differences (void between forklift receptacles and container skid), results in overloading the skid bolts, with consequent failure during rail impacts of 6- to 7-mile-per-hour velocity.

2. The maximum measured longitudinal acceleration, 17.1g at 50 milliseconds, on the XM 476 container occurred during a 7-mile-per-hour impact, with the container restrained in accordance with Figure 6.

3. The restraining arrangements illustrated in Figures 11 and 17 provide a better distribution of loads subject to railcar impacts. This improvement makes the Figure 11 arrangement substantially safer than the Figure 6 arrangement.

4. The restraining arrangement illustrated in Figure 11 has adequate structural integrity to resist longitudinal shock forces of up to 21.4g at 20 milliseconds imposed by the tested foreign railcar under impact velocities varying from 3.9 to 8.5 miles per hour.

5. During foreign railcar impacts, the longitudinal response of the mechanical shock indicators read a constant 18g from 5 to 8.5 miles per hour, thus making impractical any correlation of values obtained by electronic recording, which showed increased readings with increased impact velocity.

6. The cushioning between the cargo and the container produces substantial shock attenuation in the vertical direction and minor shock attenuation in the longitudinal and transverse directions.

IV. RECOMMENDATIONS

1. The distributed uniform loading arrangement illustrated in Figures 17 and 18 be the preferred means of restraint for Pershing missile containers XM 474, XM 475, and XM 476 on foreign railcars.

2. The distributed uniform loading arrangement in Figures 17 and 18 be evaluated in the CONUS Railway Study, Volume II of the Pershing Transportability Study.

3. The mechanical shock recording system evaluated in the tests not be used when accurate results are required.

V. FIELD EVALUATION

GENERAL

Loading and restraining procedures developed for the shipment of Pershing missile containers XM 474, XM 475, and XM 476 on CONUS railcars are incorporated in Savanna Army Depot Drawing No. 5425. Loading and restraining procedures for similar shipments on foreign railcars have not been prepared.

The cited transportability study, Reference 2, required that the CONUS railway restraining procedures be used in the foreign railway study and that an evaluation be made to determine whether a common arrangement could be established for both methods of shipment. It further stipulated that the foreign railway study would be conducted in such a manner as to provide transportability criteria and transportation influences associated with foreign railcar impacts.

DESCRIPTION OF EQUIPMENT

Two Research and Development containers, an XM 475 and an XM 476, were used in the study. A simulated XM 474 container was used to obtain the normal load transfer into the blocking arrangement. Figure 1 shows the containers loaded on the test car. Other Pershing missile containers have a similar geometry and construction; therefore, the results of the study are equally applicable to them, except for correlating the spring constants between the R&D container and the production model.

INSTRUMENTATION

The electronic instrumentation, illustrated schematically in Figure 2, consisted of strain gage accelerometers having a frequency response of from 0 to 280 cycles per second, and an automatic electrical recording system.

Specially designed dynamometers for measuring impact forces into the transport system were located between each side buffer on one end of the car and the car end sill, as illustrated in Figure 3.

Mechanical shock recorders were located on top of the XM 475 container and on the car floor adjacent to the container and the strain gage accelerometers.

Figure 1. R&D XM 475 and XM 476 Containers on Test Car (Gross Weight, 47,400 Pounds).

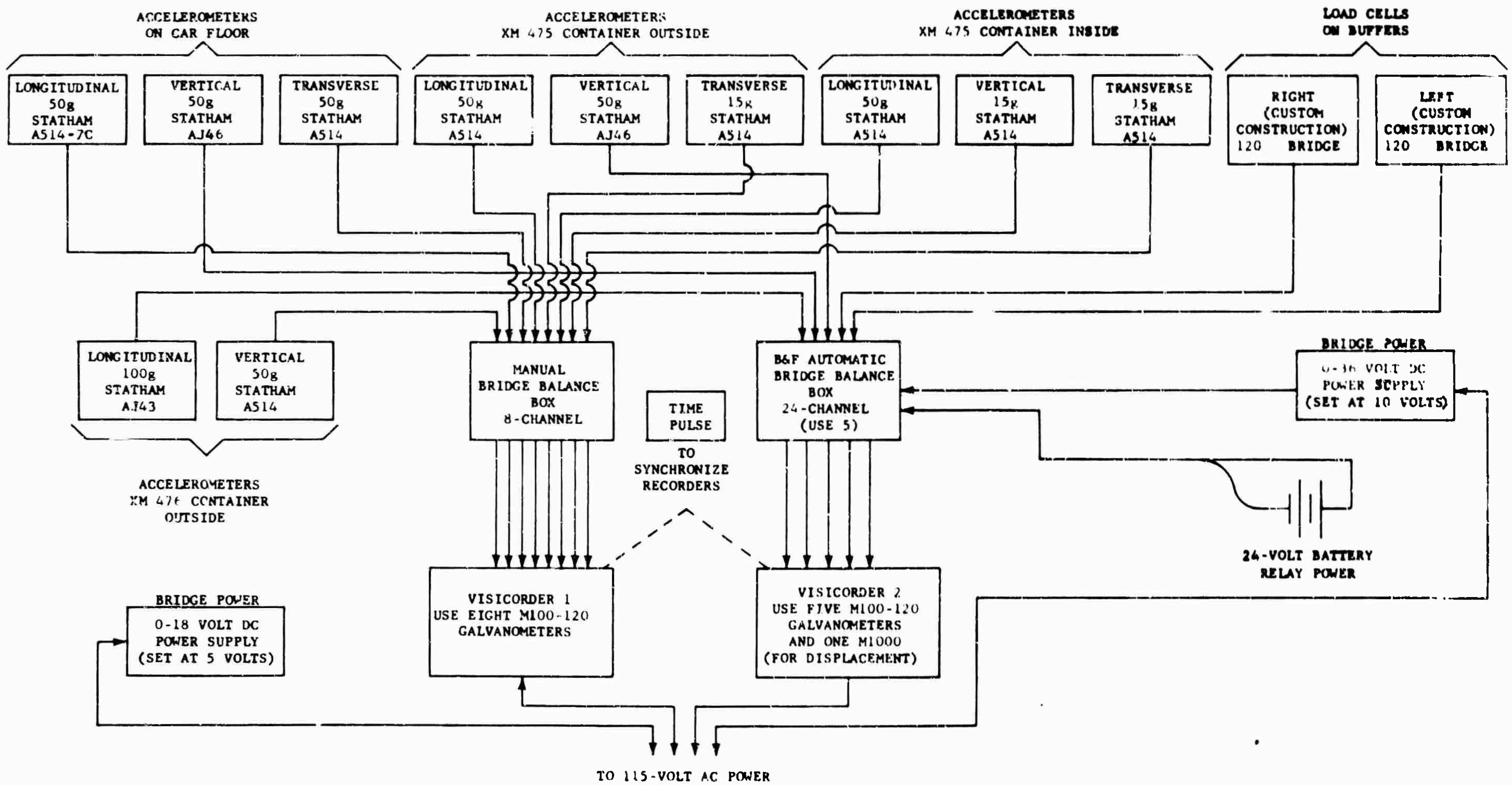


Figure 2. Schematic of Instrumentation.

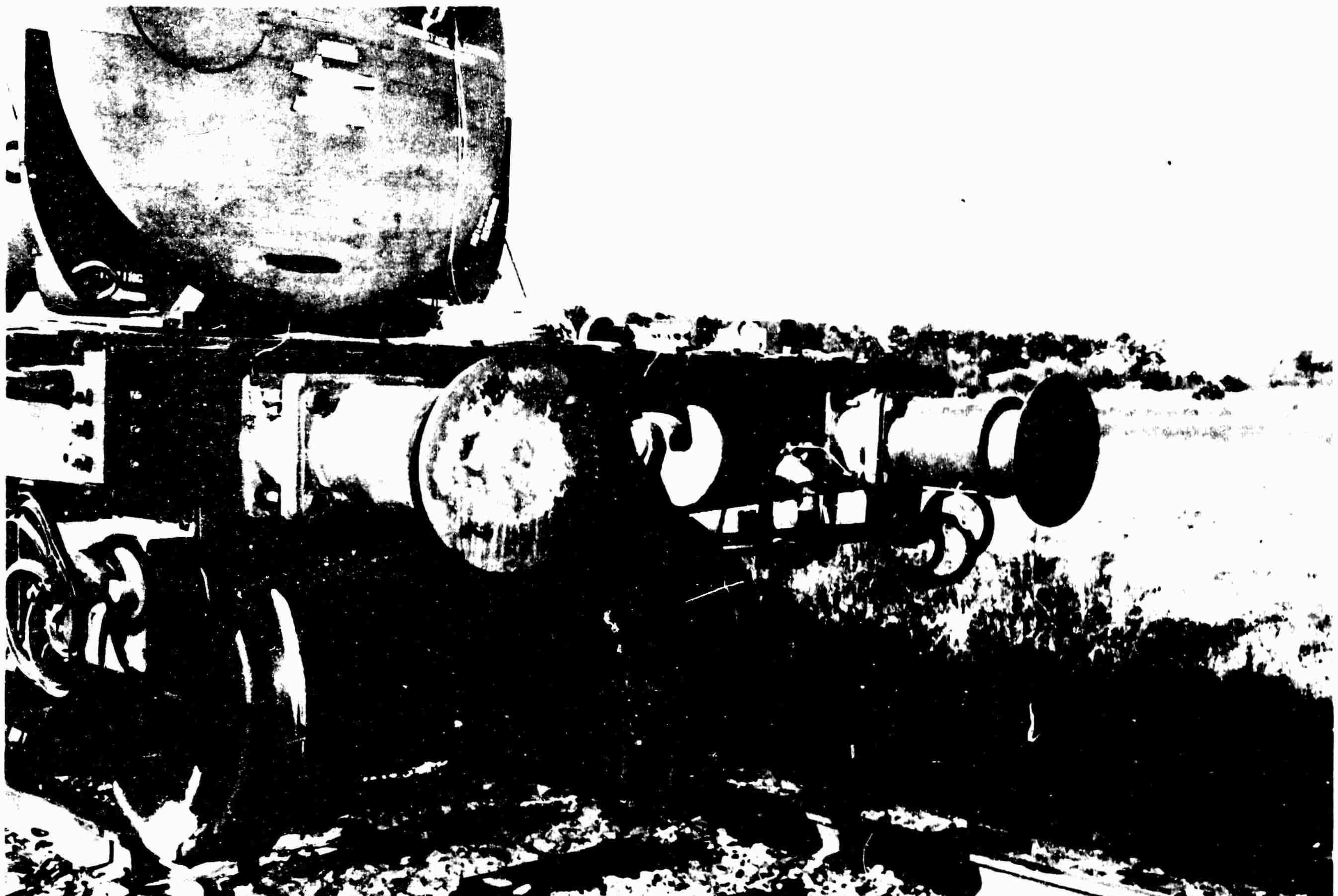


Figure 3. Dynamometers for Measuring Impact Forces.

VI. TRANSPORTATION ENGINEERING ANALYSES

The transportation engineering analyses are based on railcar impact tests, in which were used a U.S. Army flatcar, foreign-type, 40-ton, 8-wheel, as the test car (struck car) and a U.S. Army flatcar, foreign-type, 50-ton, 8-wheel, specially loaded to a gross weight amounting to 108,000 pounds, as the hammer car.

RAIL IMPACT PROCEDURES

The loaded test car is illustrated in Figure 4. The XM 475 container (right end of car) was restrained in accordance with page 4 of Savanna Army Depot Drawing No. 5425, Figure 5, except that an additional timber, approximately 2 by 4 inches, was required to fill the space between the forklift receptacles. (The space is 18½ inches wide; the three double 2-by-6-inch timbers specified in the drawing are only 16-7/8 inches wide.) This arrangement provides direct load transfer into the forklift receptacles. One-half-inch-diameter cables were used rather than 2-inch steel strapping, since the latter may not be readily available in overseas theaters.

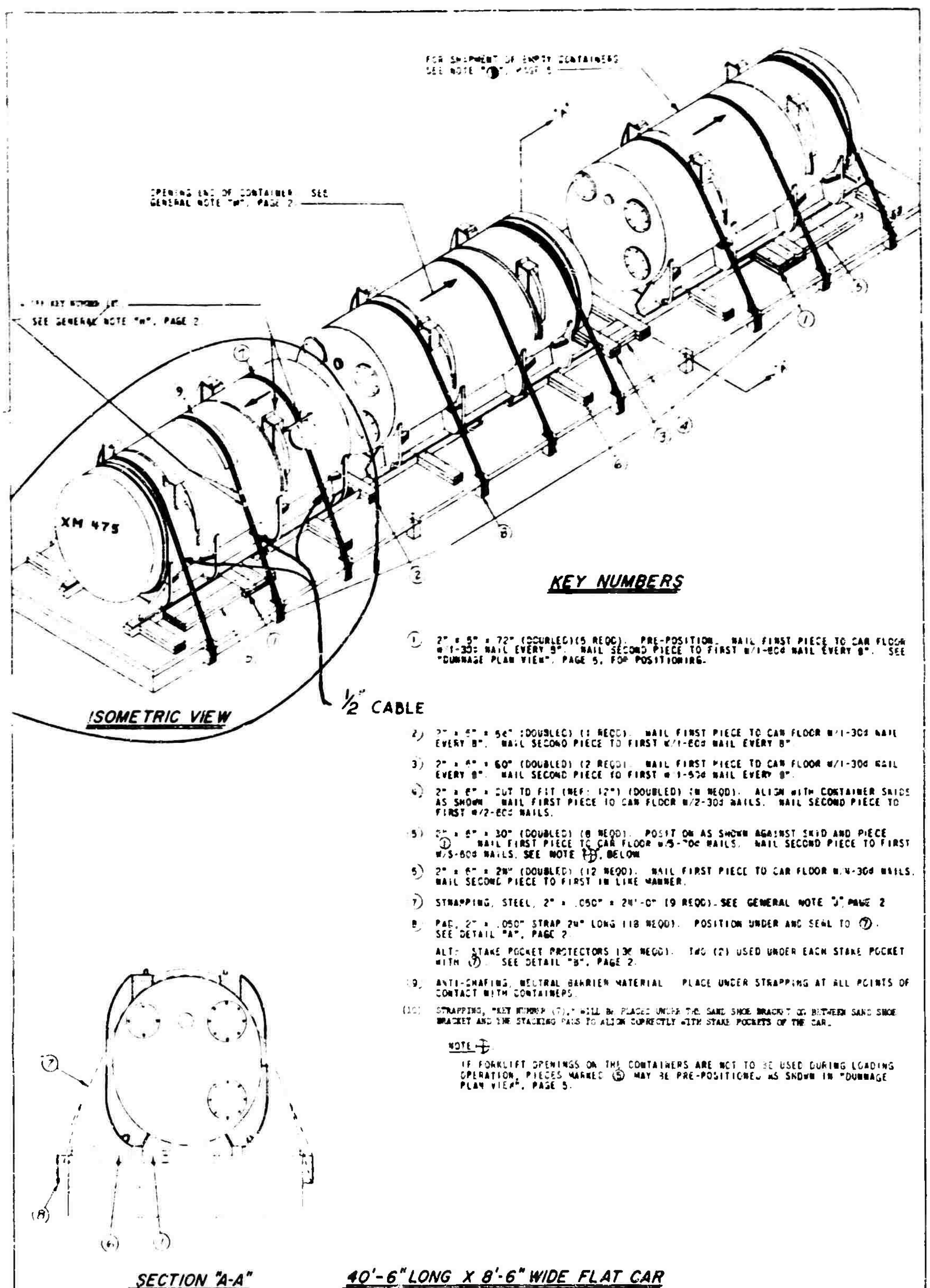
The XM 476 container was restrained in accordance with page 9 of Savanna Army Depot Drawing No. 5425, Figure 6, except that ½-inch-diameter cables were used rather than 2-inch steel strapping.

The simulated XM 474 container consisted of a 2,450-pound weight, placed in the center of the test car and blocked integrally with the XM 476 container.

The railcar impacts were conducted as illustrated in Figure 7. The relative positioning of the test equipment (hammer car, test car, and backup cars) is illustrated in Figure 8. Closeup views of the test car, the hammer car, and the first backup car are shown in Figures 4, 9, and 10 respectively.

The railcar impacts were conducted in conformance with the provisions of the cited transportability study, Reference 2 (which is a modification of TB 55-100, Transportability Criteria - Shock and Vibration), as applicable to foreign railway operation. Impact velocities for Condition A and Condition B, Figure 7, were progressively increased from 4 miles per hour (nominal) to 8 miles per hour. The test car was subjected to 14 impacts at various velocities, including 3 impacts at 8 miles per hour. The total shock force input was electronically measured at the side buffers, and the responding accelerations on the XM 475 and XM 476 containers and on the car floor adjacent to the XM 475 container were recorded on an automatic recording system.

Figure 4. Restraining Procedures Used on Containers.



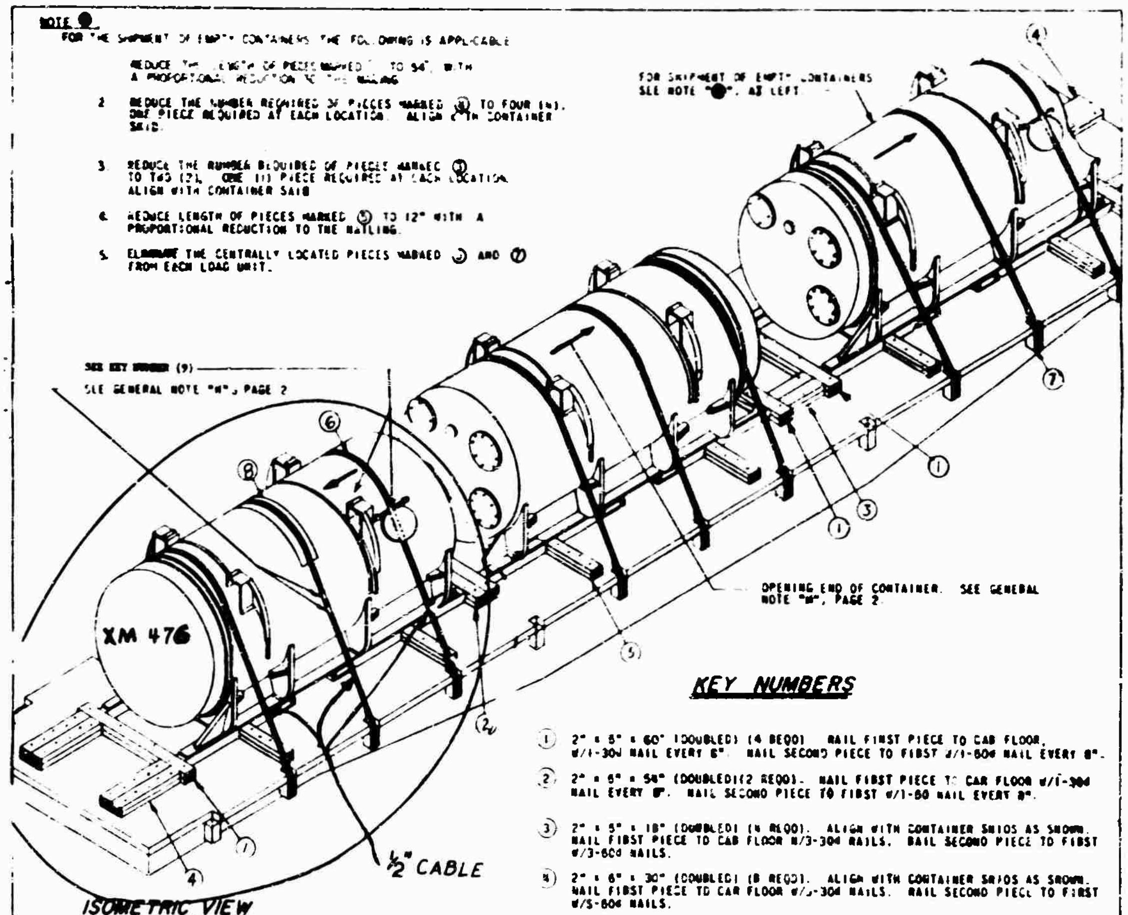
(PAGE 4)

Figure 5. Savanna Army Depot Drawing No. 5425, Page 4.

NOTE ●

FOR THE SHIPMENT OF EMPTY CONTAINERS THE FOLLOWING IS APPLICABLE

1. REDUCE THE LENGTH OF PIECES MARKED ① TO 54", WITH A PROPORTIONAL REDUCTION TO THE NAILING.
2. REDUCE THE NUMBER REQUIRED OF PIECES MARKED ④ TO FOUR (4). ONE PIECE REQUIRED AT EACH LOCATION. ALIGN WITH CONTAINER SKID.
3. REDUCE THE NUMBER REQUIRED OF PIECES MARKED ③ TO TWO (2). ONE (1) PIECE REQUIRED AT EACH LOCATION. ALIGN WITH CONTAINER SKID.
4. REDUCE LENGTH OF PIECES MARKED ⑤ TO 12" WITH A PROPORTIONAL REDUCTION TO THE NAILING.
5. ELIMINATE THE CENTRALLY LOCATED PIECES MARKED ③ AND ⑦ FROM EACH LOAD UNIT.



ISOMETRIC VIEW

KEY NUMBERS

1. 2" x 5" x 60" (DOUBLED) (4 REQD). NAIL FIRST PIECE TO CAR FLOOR, W/1-30d NAIL EVERY 6". NAIL SECOND PIECE TO FIRST W/1-60d NAIL EVERY 8".
2. 2" x 6" x 54" (DOUBLED)(2 REQD). NAIL FIRST PIECE TO CAR FLOOR W/1-30d NAIL EVERY 8". NAIL SECOND PIECE TO FIRST W/1-60 NAIL EVERY 8".
3. 2" x 5" x 18" (DOUBLED) (4 REQD). ALIGN WITH CONTAINER SKIDS AS SHOWN. NAIL FIRST PIECE TO CAR FLOOR W/3-30d NAILS. NAIL SECOND PIECE TO FIRST W/3-60d NAILS.
4. 2" x 6" x 30" (DOUBLED) (8 REQD). ALIGN WITH CONTAINER SKIDS AS SHOWN. NAIL FIRST PIECE TO CAR FLOOR W/5-30d NAILS. NAIL SECOND PIECE TO FIRST W/5-60d NAILS.
5. 2" x 6" x 24" (DOUBLED) (12 REQD). NAIL FIRST PIECE TO CAR FLOOR W/4-30d NAILS. NAIL SECOND PIECE TO FIRST IN LIKE MANNER.
6. STRAPPING, STEEL, 2" x .050" x 24'-0" (9 REQD) SEE GENERAL NOTE "J", PAGE 2
7. PAD, 2" x .050" STRAP 24" LONG (18 REQD). POSITION UNDER AND SEAL TO ⑥. SEE DETAIL "A", PAGE 2.
   ALT: STAKE POCKET PROTECTORS (36 REQD). TWO (2) USED UNDER EACH STAKE POCKET WITH ⑥. SEE DETAIL "B", PAGE 2.
8. ANTI-CHAFING, NEUTRAL BARRIER MATERIAL. PLACE UNDER STRAPPING AT ALL POINTS OF CONTACT WITH CONTAINERS.
9. STRAPPING, "KEY NUMBER (6)," WILL BE PLACED UNDER THE SAND SHOE BRACKET OR BETWEEN SAND SHOE BRACKET AND THE STACKING PADS TO ALIGN CORRECTLY WITH STAKE POCKETS OF THE CAR.

BILL OF MATERIAL		
LUMBER	LINEAL FEET	BOARD FEET
2" x 6"	158	158
NAILS	NO. REQD	POUNDS
30d (4-1/2") 60d (5")	190 94	9-3/4 9-1/2
STRAPPING, STEEL, 2" x .050" - - - -252' REQD - - - 84 LBS		
ANTI-CHAFING MATERIAL - - - - - - - - AS REQD		

LOAD AS SHOWN

ITEM	QUANTITY	WEIGHT (APPROX)
MOTOR, FIRST STAGE	3	27,579 LBS
DUNNAGE		499 LBS
TOTAL WEIGHT		29,078 LBS (APPROX)

46'-6" LONG X 8'-6" WIDE FLAT CAR

(PAGE 9)

Figure 6. Savanna Army Depot Drawing No. 5425, Page 9.

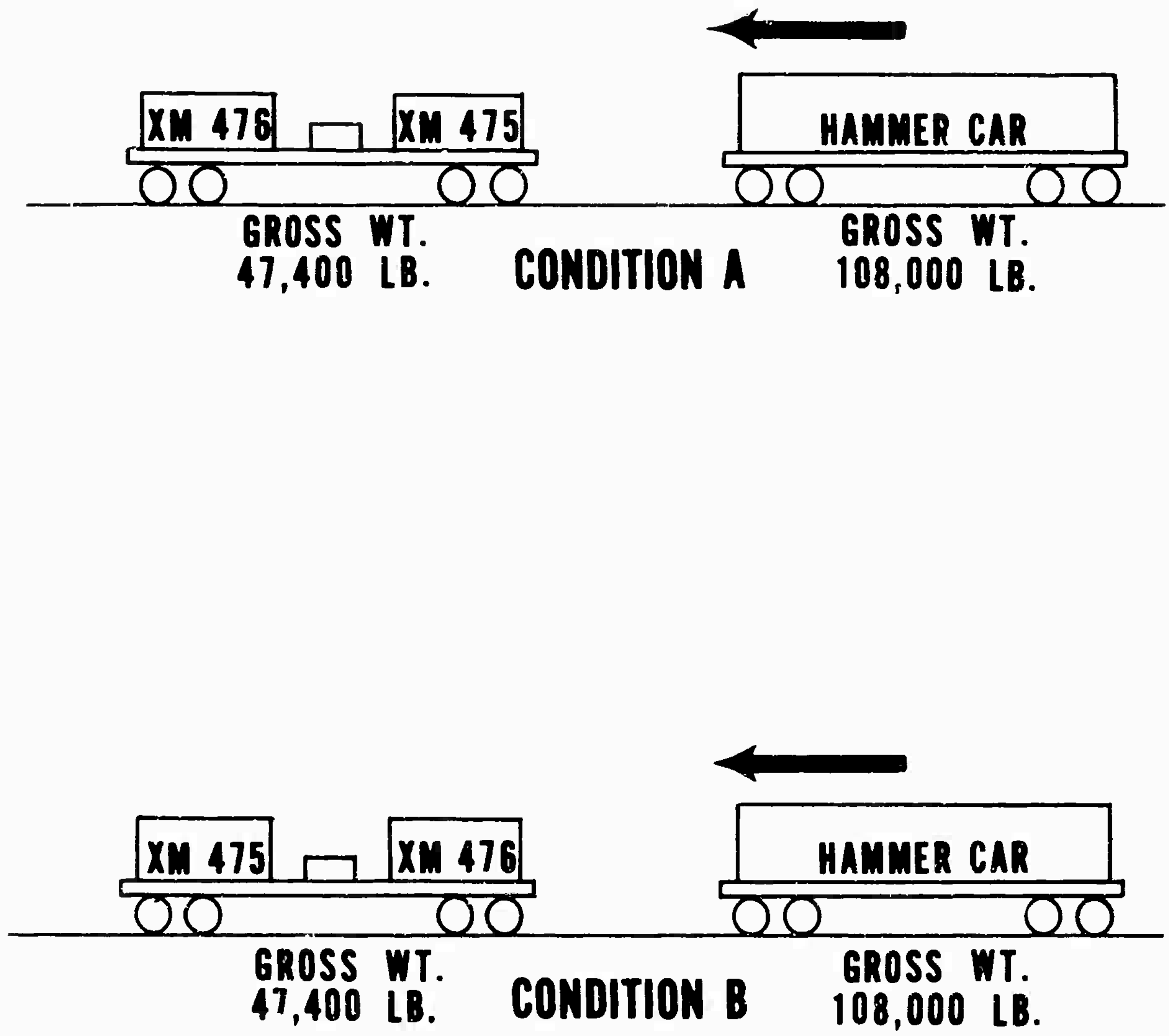


Figure 7. Tvpes of Impacts.

Figure 8. Positioning of Rail Equipment for Impact Tests.

Figure 9. Hammer Car (Gross Weight, 108,000 Pounds).

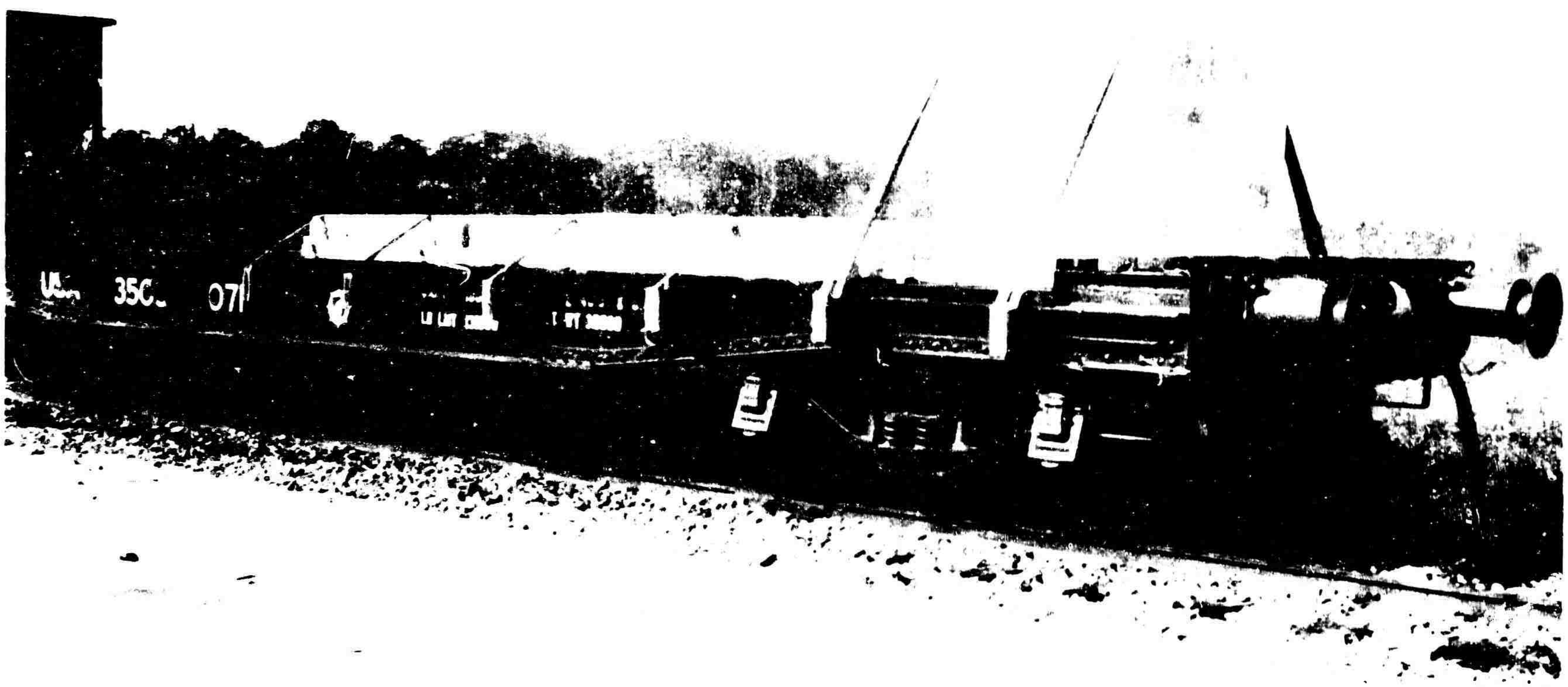


Figure 10. First Backup Car.

RAIL IMPACT RESULTS

Container Restraint Arrangements

The restraining arrangement used on the XM 475 container, exhibited on page 4 of Savanna Army Depot Drawing No. 5425 (Figure 5) and more explicitly in Figure 11, sustained the combined dynamic loadings resulting from the 14 railcar impacts (Conditions A and B) without any apparent damage.

The restraining arrangement used on the XM 476 container, illustrated on page 9 of Savanna Army Depot Drawing No. 5425 (Figure 6), sustained the combined dynamic loadings resulting from Conditions A and B of the test. However, during Condition B and at an impact velocity of 6.8 miles per hour (measured longitudinal shock force input on the container - 17.1g), the two bolts attaching the aft rear skid to the container structure (impacted end of the container and railcar) experienced a shear failure. The bolt failure occurred on a skid that was not abutted flush with the forklift receptacle. Prior to failure, the XM 476 had sustained rebound impacts resulting from five Condition A impacts and three direct Condition B impacts. (All these impacts were less severe than the impact when failure occurred.)

Transport System Results

The transportability criteria resulting from the railcar impacts are the maximum recorded peak values. All recorded peak values are contained in Tables 1 through 5. As indicated in these tables, the maximum recorded values usually occur at the impacted end of the test car; therefore, correlation of the results will be made from the values recorded at the impacted end.

The side buffer force for the various impacts is presented graphically in Figure 12. Also, correlation is made between buffer force and the recorded car floor longitudinal accelerations. The car floor accelerations become asymptotic at a velocity of 6 miles per hour; therefore, recorded values above 6 miles per hour have no significant meaning. The accelerations on the car floor above 6 miles per hour exceeded the rated capacity of the accelerometer.

The longitudinal, vertical, and transverse peak values recorded on the XM 475 container, exterior and interior, during Condition A are compared in Figures 13-15. Figure 13 indicates that the longitudinal responses of the container, exterior and interior, are similar up to about a 6-mile-per-hour impact velocity. Above that velocity, the carriage suspension system provides only a small gain in the shock attenuation up to impact velocities of 8.5 miles per hour. Figure 14 shows, however, that the carriage suspension system does effectively attenuate the imposed vertical accelerations. The transverse results (Figure 15) show that maximum attenuation is obtained at an impact velocity of approximately 6 miles per hour; and that, at higher impacts, the behavior of the carriage assumes an erratic response.

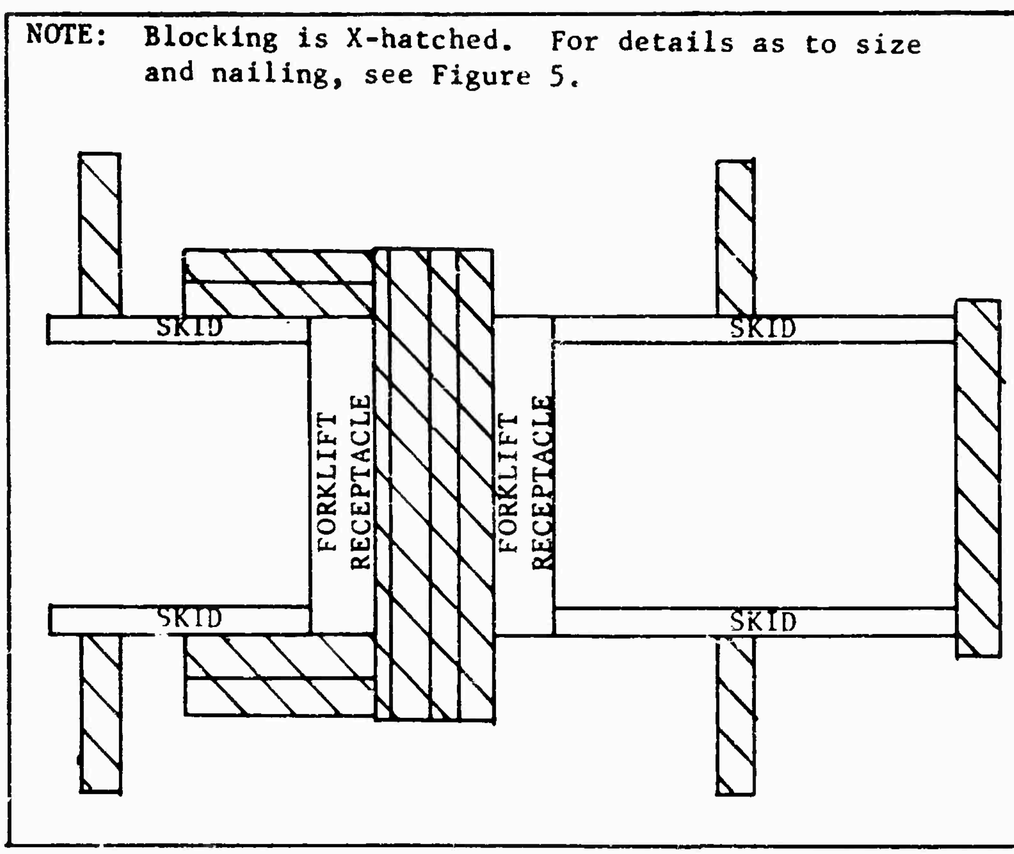


Figure 11. Blocking Arrangement for XM 475.

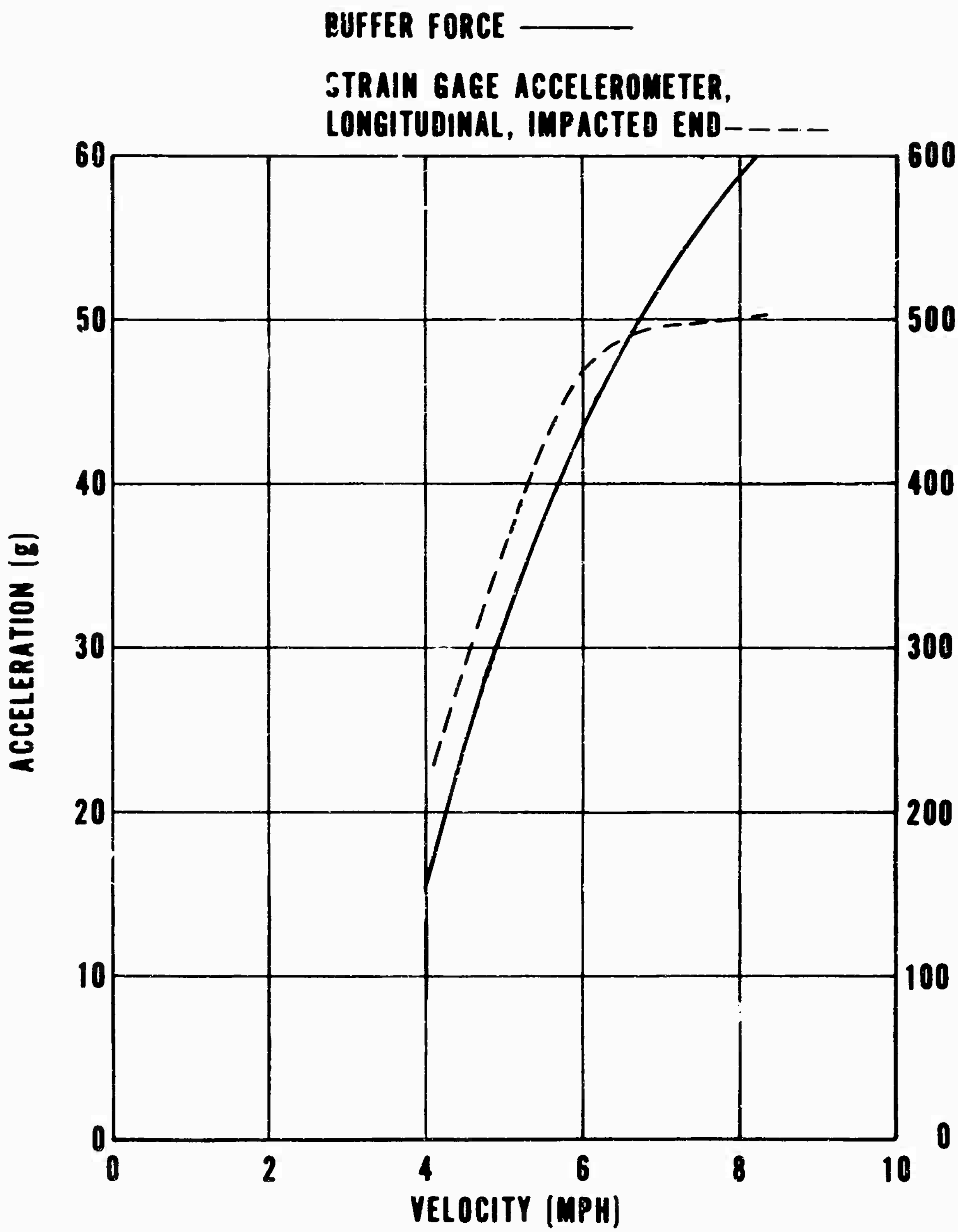


Figure 12. Buffer Force Versus Longitudinal Acceleration (Car Floor).

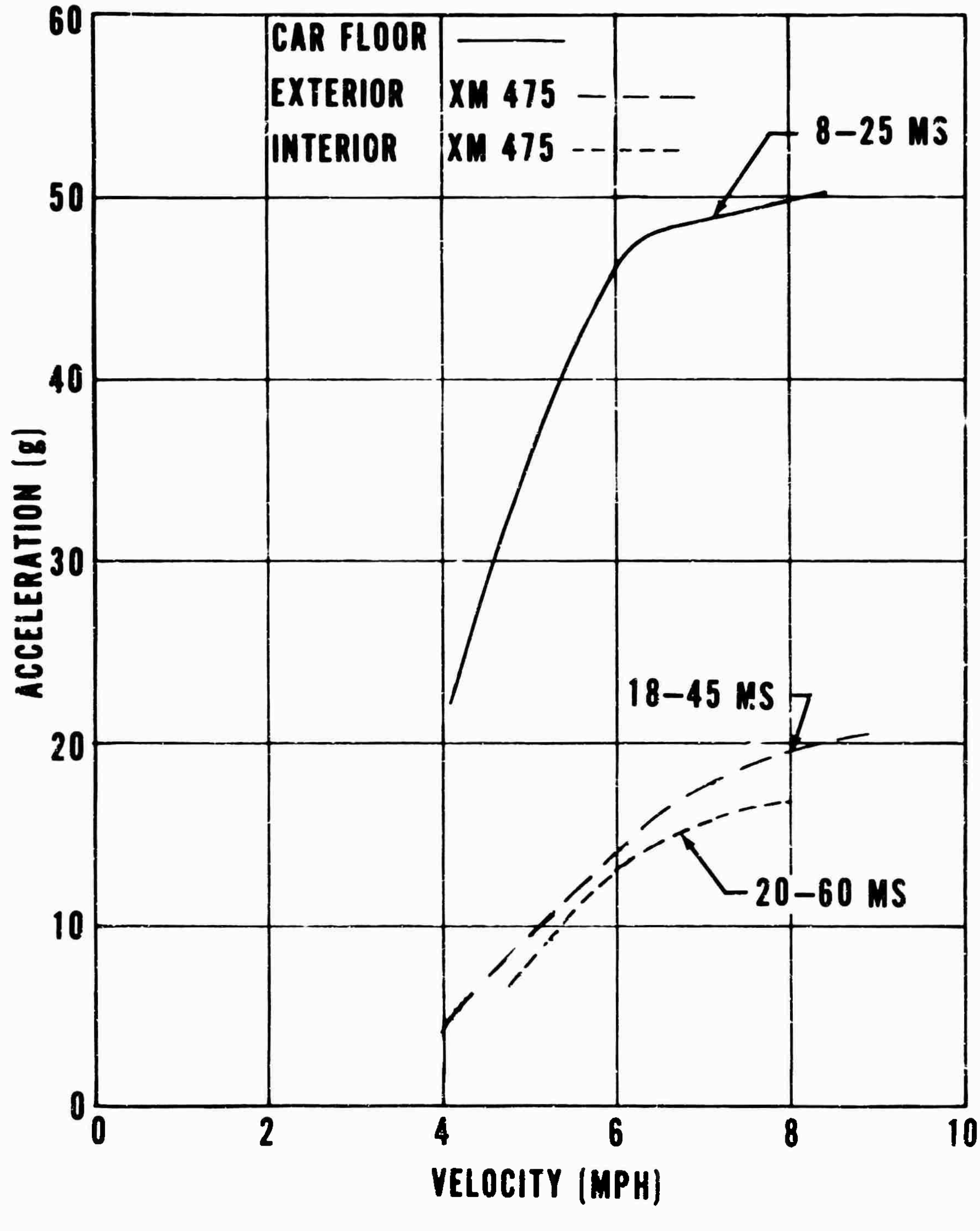


Figure 13. Longitudinal Accelerations - Car Floor and Exterior and Interior of XM 475 (XM 475 on Impacted End of Car).

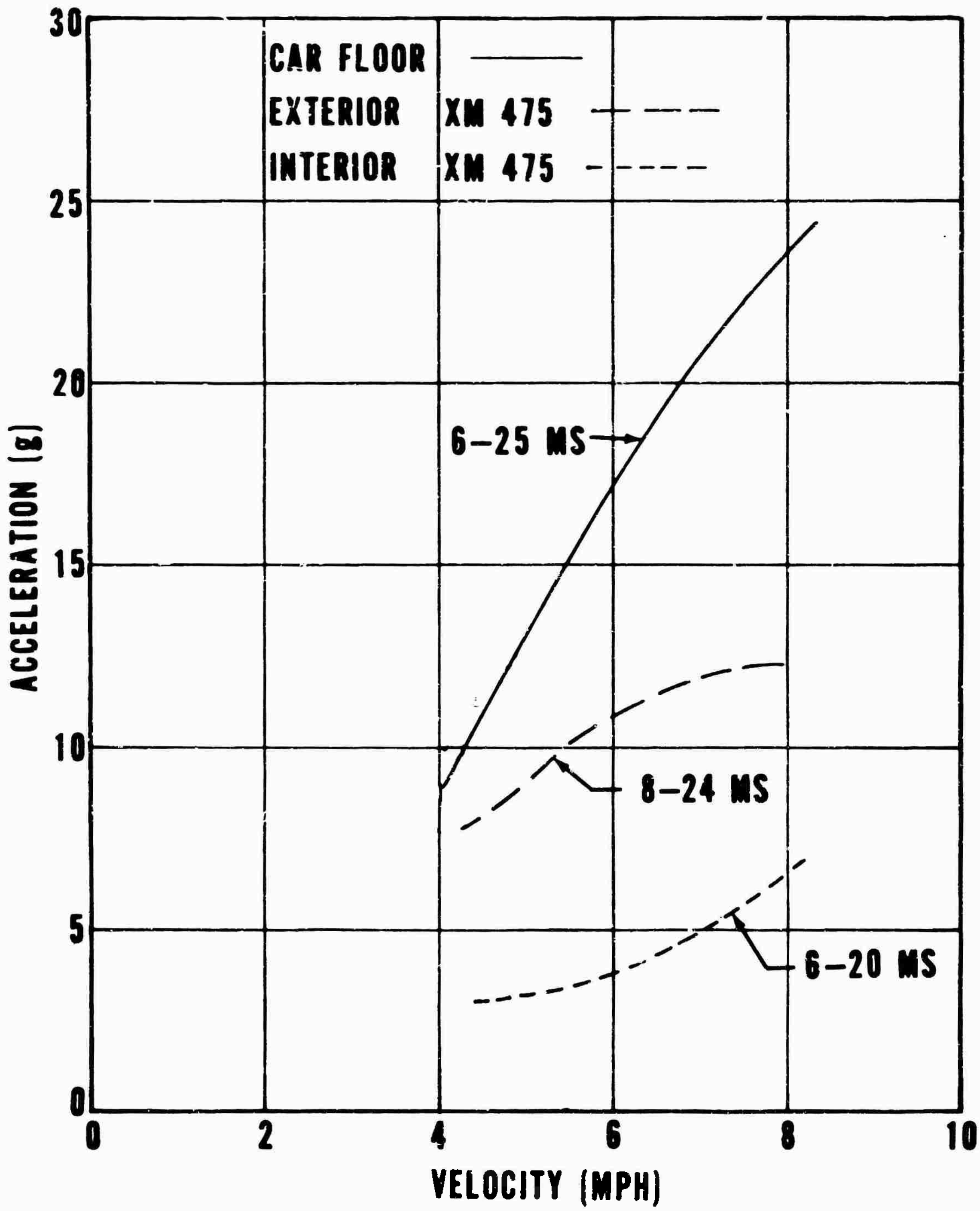


Figure 14. Vertical Accelerations - Car Floor and Exterior and Interior of XM 475 (XM 475 on Impacted End of Car).

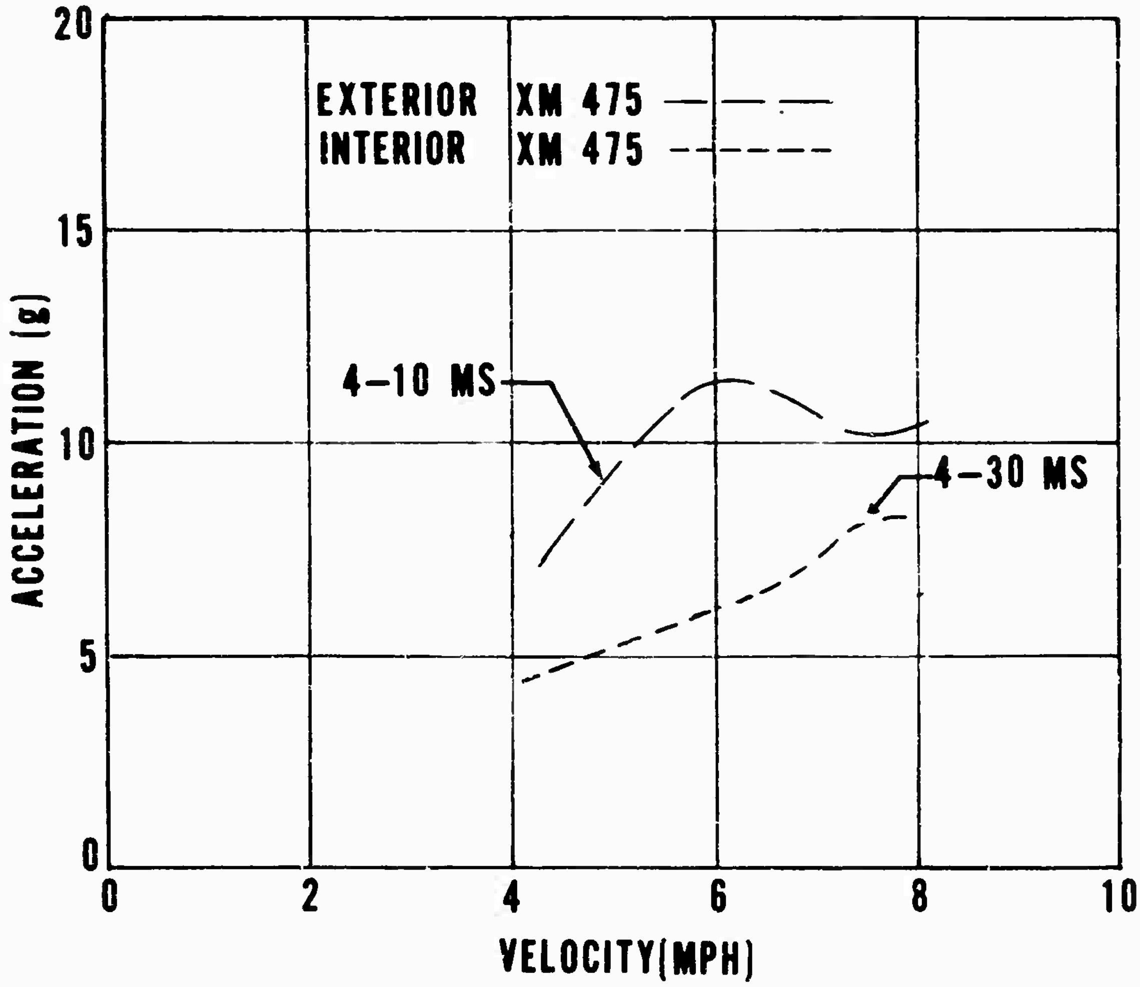


Figure 15. Transverse Accelerations - Exterior and Interior of XM 475 (XM 475 on Impacted End of Car).

The recorded peak values on the XM 476 container under Condition B (occurring during the 7.8-mile-per-hour impact velocity) were 14.5g longitudinally and 10.9g vertically. These values correspond similarly to those obtained on the XM 475 container.

Electronic and Mechanical Recording Results

Results of the electronic and mechanical recording systems located on the car floor and oriented longitudinally are compared in Figure 16. The figure shows that a correlation between the electronic and the mechanical recording systems at impact velocities above 5 miles per hour cannot be obtained, and that the maximum capacity of the mechanical recording system is approximately 18g. The mechanical recording system located on the exterior of the XM 475 container recorded in a similar manner.

TRANSPORT SYSTEM ANALYSIS

Container Shock Mounting System

The interior carriage structure is mounted on a three-degree-of-freedom shock-absorbing system. A comparison of peak-response values on the exterior and interior of the XM 475 showed that maximum attenuation occurred in the vertical plane and that attenuation in the longitudinal and transverse planes was relatively small.

Recording Systems

Peak values from the electronic and mechanical recording systems were compared in all three planes for both the car floor and the exterior of the XM 475. The results showed that while correlation was possible in a narrow range, the mechanical recording system did not produce accurate results. In view of this, the mechanical recording system is not recommended for use when accurate results are required.

Container Restraint Arrangement

Each container skid is attached to the base structure of the container with two ½-inch-diameter bolts. On some containers the ends of the skids are not abutted flush against the forklift receptacles. When this condition exists and impact loads are applied to the ends of the skids, the entire load must be carried by the ½-inch-diameter bolts, in shear. The tests demonstrated that transportation loads resulting from rail impacts will cause failure of the bolts.

A theoretical analysis, based on the recorded acceleration on the exterior of the XM 476 when the bolt failures occurred, shows that the bolts are structurally inadequate under the following conditions:

1. End blocking method is used.

2. Skid is not abutted flush against the forklift receptacles.

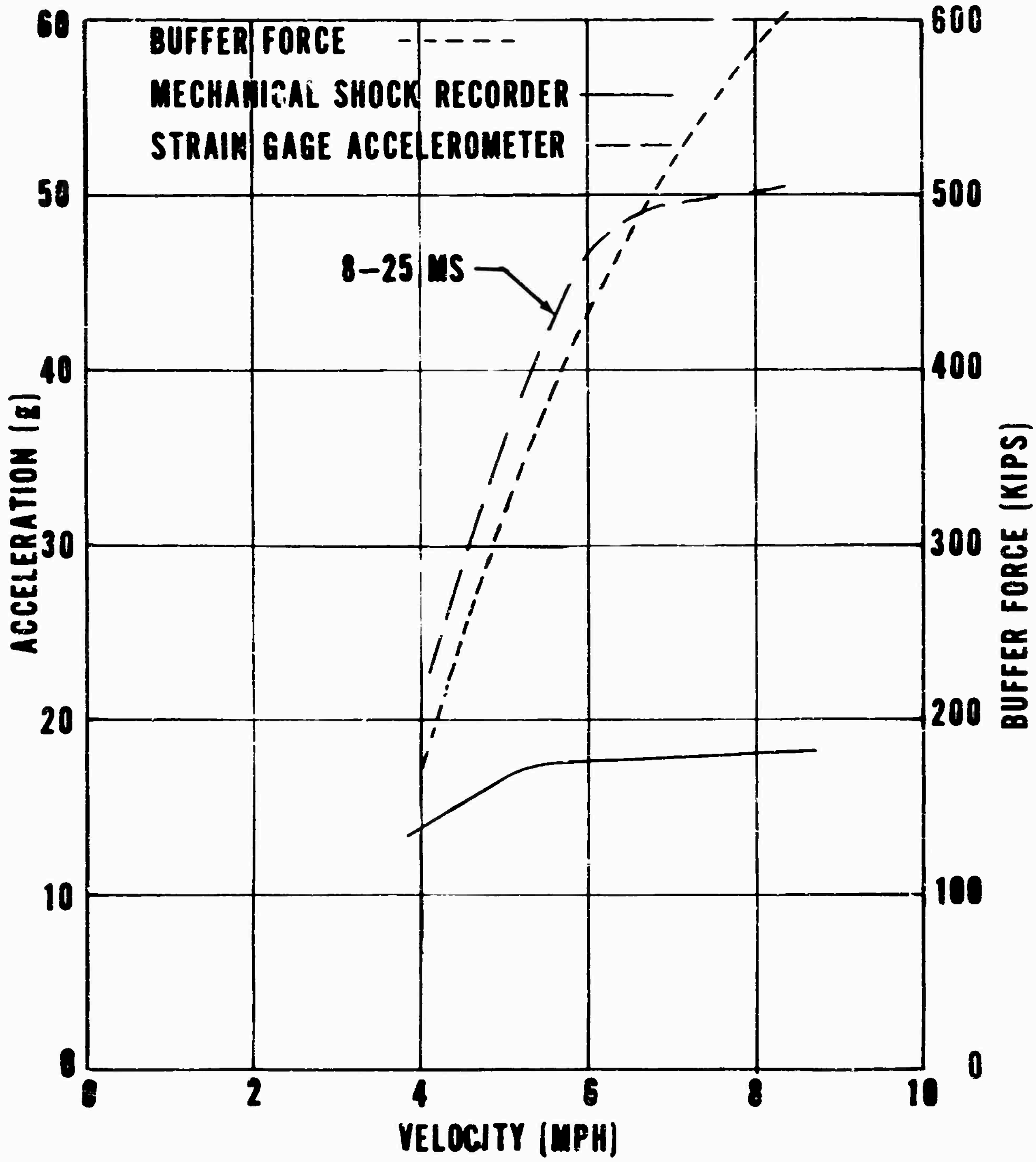


Figure 16. Longitudinal Accelerations on Car Floor: Mechanical Shock Recorder Versus Strain Gage Accelerometer (Instruments on Impacted End of Car).

3. Coefficient of friction steel on oak is 0.6.

4. The relatively small shear resistance developed between the base structure of the container and the skid due to bolt tension and prestress on the cables is neglected, because the tightness of the bolts is questionable and most of the prestress on the cables will be relieved after several impacts.

The recorded longitudinal acceleration on the exterior of the XM 476 container was 17.1g when bolt failure occurred.

Total shearing force on bolts:

$$F_s = \frac{Wa}{g} - F_F$$

$$= \frac{7322}{g} \times 17.1g - 0.6 \times 7322 = 120{,}620 \text{ lb.}$$

Shearing stress on one bolt:

$$f_s = \frac{120{,}620}{4 \times 0.1963} = 153{,}600 \text{ lb./in.}^2$$

The shearing stress far exceeds the ultimate shearing stress for high strength steels.

Of the two restraining arrangements evaluated, the arrangement shown in Figure 11 provides greater structural integrity since longitudinal loads are transmitted to the base structure through the forklift receptacles rather than through the skids, which are inherently weak.

Recommended Restraining Arrangement

A distributed uniform loading arrangement that is applicable to the XM 474, XM 475, and XM 476 containers was developed. See Figures 17 and 18. In addition to replacing the many arrangements depicted in Savanna Army Depot Drawing No. 5425, the arrangement shown in Figures 17 and 18 offers the following advantages over the arrangement illustrated in Figure 11:

1. Prepositioning of the transverse blocking is not required, since no nails are required under the container.

2. Less longitudinal space on the car is required.

3. The longitudinal blocking members also provide transverse restraint, which simplifies the arrangement.

In view of its simplicity and the other advantages enumerated, the restraining arrangement illustrated in Figures 17 and 18 is recommended for rail shipment of the XM 474, XM 475, and XM 476 containers.

NOTES

1. Blocking material will consist of hardwood, spruce, fir, larch, hemlock or dense southern yellow pine of the following species: long-leaf, slash and/or loblolly, straight grained, free from decay and strength impairing knots.

2. Blocking is X-hatched. All doubled 2x6s except 2x4 filler, 30d nails bottom piece, 60d top piece, 6" C.C.

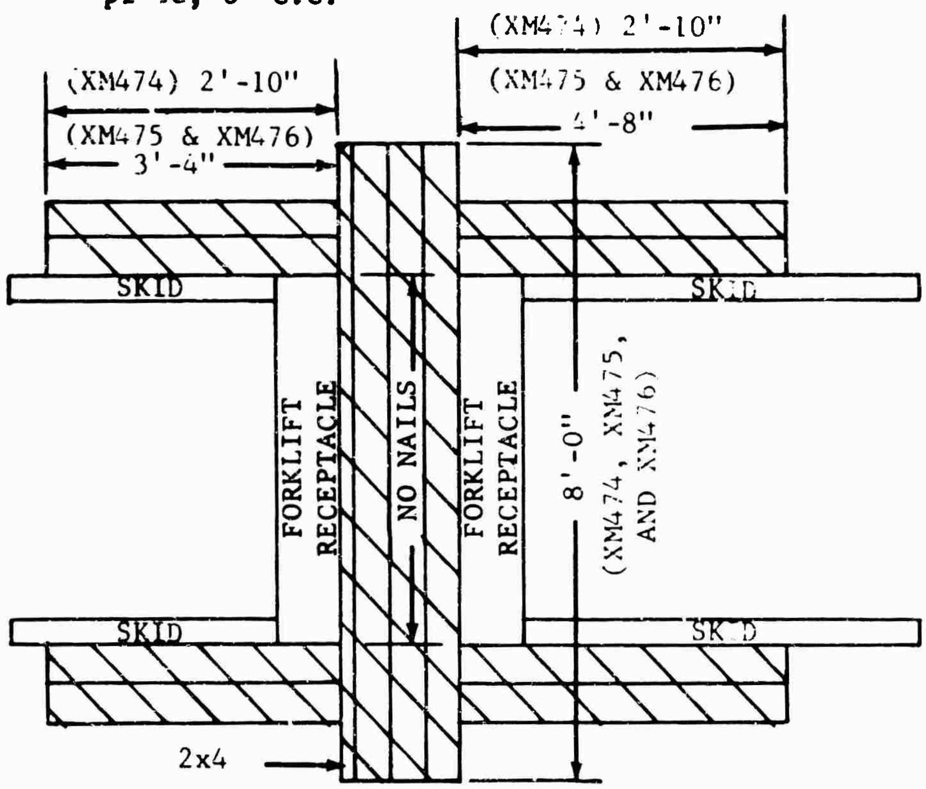


Figure 17. Distributed Uniform Loading Arrangement for the XM 474, XM 475, and XM 476 Containers.

NOTES

1. Only two cables are required for the XM 474.

2. If available, 2"x.05" steel strapping, doubled, may be used in lieu of cable. If used: seal lap joint with two seals, two crimps per seal; provide antichafing material (canvas) at all points of contact with container; protect all straps at bottom of stake pockets with 12-to-16 gage sheet metal or equivalent.

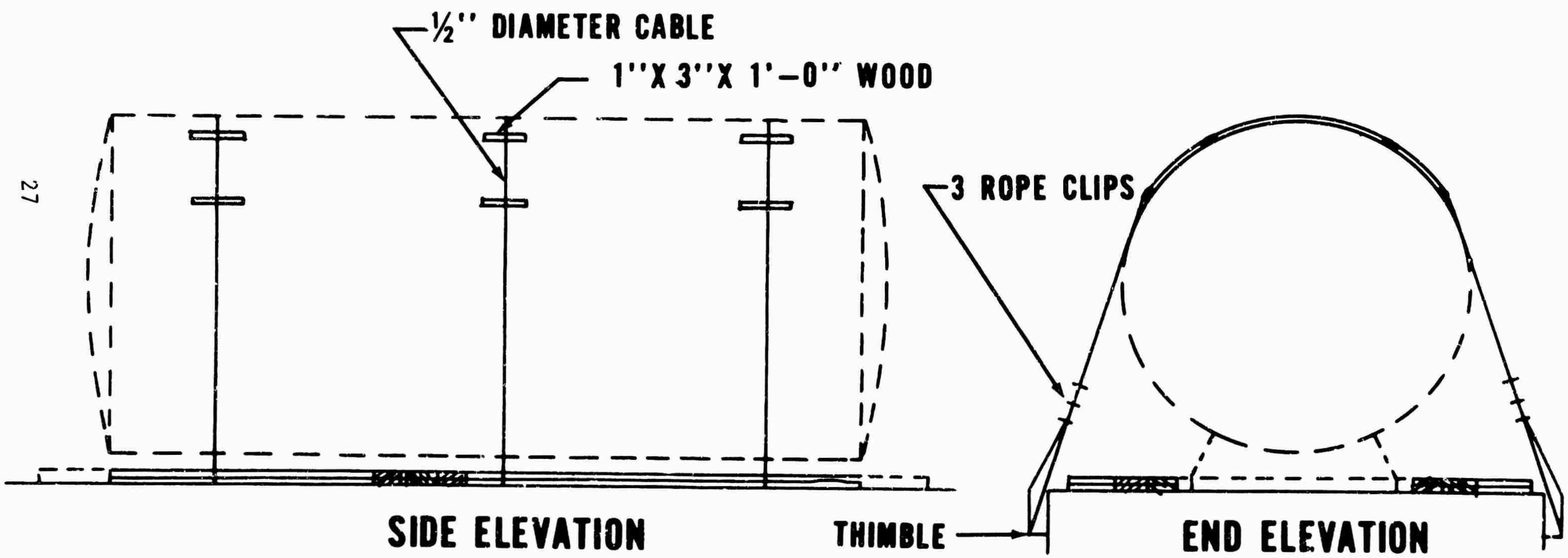


Figure 18. Vertical Restraint for XM 474, XM 475, and XM 476 Containers.

VII. REFERENCES

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ANNEX

DOCUMENTATION TABLES

TABLE 1
ALL LONGITUDINAL CHANNELS

Impact Velocity (mph)	Condition	Car Floor (g)	Car Floor (ms)*	Exterior XM475 (g)	Exterior XM475 (ms)	Interior Carriage XM475 (g)	Interior Carriage XM475 (ms)	Exterior XM476 (g)	Exterior XM476 (ms)
4.05	A	21.9	25	4.5	45	6.1	30	3.2	35
4.2	A	29.5	8	6.4	20	5.5	32	5.1	25
4.8	A	28.3	12	8.0	25	6.6	30	6.1	12
5.1	A	37.1	20	9.1	30	8.6	40	6.7	50
6.2	A	45.9	25	14.0	25	13.5	35	8.4	40
6.2	A	49.5	16	16.4	20	14.2	60	10.3	24
7.4	A	48.8	15	18.6	20	15.9	35	9.1	40
7.6	A	49.8	15	21.4	20	17.0	20	7.9	40
8.5	A	50.5	12	18.2	18	16.7	35	12.3	36
3.9	B	14.6	12	4.7	15	4.4	25	6.2	18
4.3	B	31.4	8	7.3	16	7.2	30	8.7	22
5.7	B	43.9	8	14.5	20	11.1	30	9.9	24
6.8	B	45.9	12	15.5	15	12.8	32	17.1	50
7.8	B	50.7	12	16.4	16	13.3	30	14.5	50

*Pulse time in milliseconds.

TABLE 2

ALL VERTICAL CHANNELS

Impact Velocity (mph)	Condition	Car Floor (g)	Car Floor (ms)*	Exterior XM475 (g)	Exterior XM475 (ms)	Interior Carriage XM475 (g)	Interior Carriage XM475 (ms)	Exterior XM476 (g)	Exterior XM476 (ms)
4.05	A	8.7	8	7.6	8	3.9	15	3.2	35
4.2	A	10.0	25	7.7	8	3.1	10	[illegible]	8
4.8	A	12.5	4	9.6	8	2.9	16	7.6	4
5.1	A	12.7	7	8.1	8	2.6	6	6.4	6
6.2	A	15.7	7	11.7	8	4.7	20	8.6	4
6.2	A	20.5	6	10.6	10	3.3	16	9.8	4
7.4	A	27.5	7	12.4	24	3.9	4	9.3	4
7.6	A	22.2	6	11.9	24	6.8	12	10.0	4
8.5	A	24.1	10	11.9	8	8.5	6	13.6	4
3.9	B	3.6	12	3.3	8	2.9	6	7.6	4
4.3	B	7.1	12	4.9	8	2.7	8	6.5	4
5.7	B	8.3	12	5.3	6	4.5	6	13.0	6
6.8	B	10.6	8	8.1	15	3.5	8	10.3	8
7.8	B	15.5	6	12.0	8	7.3	20	10.9	4

*Pulse time in milliseconds.

TABLE 3
ALL TRANSVERSE CHANNELS

Impact Velocity (mph)	Condition	Exterior XM 475 (g)	Exterior XM 475 (ms)*	Interior Carriage XM 475 (g)	Interior Carriage XM 475 (ms)
4.05	A	8.0	8	4.5	8
4.2	A	6.7	8	4.2	6
4.8	A	6.3	8	6.0	4
5.1	A	11.0	6	4.1	6
6.2	A	11.8	6	6.0	4
6.2	A	11.3	8	6.3	12
7.4	A	10.8	10	9.3	8
7.6	A	9.5	10	7.3	10
8.5	A	12.5	4	7.7	30
3.9	B	4.2	6	4.2	4
4.3	B	4.8	4	2.9	8
5.7	B	6.9	6	4.8	6
6.8	B	7.1	14	6.3	18
7.8	B	12.3	8	9.0	4

*Pulse time in milliseconds.

TABLE 4
BUFFER FORCE

Impact Velocity (mph)	Condition	Load Cell No. 1 (kips)	Load Cell No. 2 (kips)	Total Force (kips)
4.05	A	65.8	75.0	141
4.2	A	62	153	215
4.8	A	114	156	270
5.1	A	132	244	376
6.2	A	171	306	477
6.2	A	125	250	375
7.4	A	184	311	575
7.6	A	185	410	595
8.5	A	131	454	585
3.9	B	96.6	86.7	183
4.3	B	119	158	277
5.7	B	102	240	342
6.8	B	136	306	442
7.8	B	142	417	559

TABLE 5

MECHANICAL SHOCK RECORDER DATA

Impact Velocity (mph)	Condition*	Recorder on Car Floor Acceleration (g)			Recorder on Exterior XM475 Acceleration (g)		
		Long.	Vert.	Trans.	Long.	Vert.	Trans.
4.05	A	14.3	5.1	10.1	8.4	2.6	3.8
4.2	A	14.1	10.5	11.5	8.8	1.9	6.4
4.8	A	15.7	12.5	10.5	8.4	4.1	4.7
5.1	A	17.4	9.2	9.6	15.7	4.1	5.5
6.2	A	17.9	12.8	9.7	18.2	8.4	13.2
6.2	A	17.0	14.5	12.3	18.2	13.1	5.1
7.4	A	18.3	15.1	14.2	18.3	10.2	9.0
7.6	A	17.5	15.7	13.8	18.0	13.3	12.5
8.5	A	18.0	15.5	16.5	17.8	10.9	7.7
3.9	B	14.8	9.3	9.0	4.7	1.8	3.8
4.3	B	17.7	4.1	8.7	6.8	4.5	3.8
5.7	B	17.9	9.0	10.6	13.1	4.1	3.7
6.8	B	18.4	11.3	10.9	17.3	8.3	5.5
7.8	B	18.4	10.9	11.8	17.7	8.7	7.2

*For condition A, both mechanical recorders were located on impacted end of car.

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13 ABSTRACT

Foreign railcars were used in conducting rail impact tests on Pershing missile system first and second stage motor containers, XM 475 and XM 476. Data from the tests will be used in evaluating the effects of the foreign rail environment on the containers and in determining if the procedures used in restraining the containers for CONUS rail shipment would be applicable to foreign rail shipment.

The CONUS rail shipment restraining arrangement evaluated during this study was basically in conformance with pages 4 and 9 of Savanna Army Depot Drawing No. 5425.

Dynamic loadings induced by impacting the test car were measured electronically. The input forces were determined at impact by specially designed dynamometers mounted between the buffers and the car end sill. The car and container responses were measured by strain gage accelerometers.

Results of the study showed that the container skid bolts do not have the required structural strength to resist the dynamic loading imposed by rail impacts. The ½-inch-diameter bolts attaching the skid to the container experienced shear failure at impact velocities of 7 miles per hour when the container skid was not abutted flush with the forklift receptacle.

The results of the study also indicated that the restraining arrangement providing transfer of shocks into the forklift receptacle rather than to the container skids is the preferred arrangement.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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